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CLASSIFICATION, COMPOSITION IDENTIFICATION, SORTING AND LABELLING OF TEXTILE WASTE

Deliverable 1.3

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TABLE OF ABBREVIATIONS

Abbreviation	Definition
M	Month
EU	European Union
WP	Work Package
KPI	Key Performance Indicator
EC	European Commission
ESPR	Ecodesign for Sustainable Products Regulation
EPR	Extended Producer Responsibility
DPP	Digital Product Passport
NIRS	Near Infrared Spectroscopy

EXECUTIVE SUMMARY

This document constitutes Deliverable D1.3 "Classification, Composition Identification, Sorting and labelling of Textile Waste" of the European project "Fostering circularity in textile: innovative interoperable solutions and best practices for implementation and harmonization of EPR schemes", also known by its acronym "Circula-TEX"

Deliverable D1.3 outlines the scope of Task T1.3, titled "Collaborative analysis: methods for classification, composition identification, sorting and labelling systems", dedicated to the outlining of gaps and issues related to the initial phases of textile waste value chain. The goal of the present task is to understand how to improve quality and efficiency of separate collection and sorting practices.

The present report summarizes the results of the co-creation process on waste classification, composition identification, and sorting of textile waste including how the labelling systems could be improved (gaps, requirements, potential solutions).

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3. INTRODUCTION

The transition towards a circular textile economy represents one of the main challenges identified by the European Union within the framework of the EU Strategy for Sustainable and Circular Textiles. The textile sector is characterised by increasing material complexity, fragmented value chains, insufficient collection and sorting infrastructures, and limited availability of high-quality secondary raw materials. These challenges are further amplified by the growing volumes of textile waste generated annually in Europe and by the upcoming implementation of mandatory separate collection systems and Extended Producer Responsibility (EPR) schemes for textiles.

In this context, the Circula-TEX project aims to support the transformation of the textile value chain by fostering interoperability, harmonisation and practical implementation of circular solutions. Through a multidisciplinary and multi-stakeholder approach, the project seeks to identify barriers, opportunities and best practices that can facilitate the transition towards more efficient and economically viable circular textile systems.

Task T1.3, entitled *"Collaborative analysis: methods for classification, composition identification, sorting and labelling systems"*, addresses one of the most critical bottlenecks of textile circularity: the ability to correctly identify, classify, sort and trace textile products and textile waste throughout their lifecycle. These activities represent a prerequisite for high-quality reuse, repair, remanufacturing and recycling, as well as for the development of effective EPR systems and eco-modulation mechanisms.

The increasing diversification of textile products, the widespread use of fibre blends, coatings, additives and complex product constructions, together with the lack of harmonised classification systems, currently limit the efficiency of collection, sorting and recycling operations. At the same time, emerging regulatory initiatives such as the Ecodesign for Sustainable Products Regulation (ESPR), the Digital Product Passport (DPP), and the revision of the Waste Framework Directive are creating new opportunities for improving traceability, transparency and circularity within the textile sector.

The objective of Task T1.3 is therefore to identify existing practices, technological solutions, operational barriers and stakeholder requirements related to:

- collection of textile waste;
- classification systems;
- composition identification methods;
- sorting technologies and practices;
- labelling and traceability systems.

To achieve this objective, a co-creation process involving both internal project partners and external stakeholders was implemented. The consultation covered actors representing different positions within the textile value chain, including brands, manufacturers, collectors, sorters, reuse operators, recyclers, technology providers, research organisations and waste-management companies. Their perspectives were collected through structured interviews and collaborative workshops, allowing the identification of common challenges, diverging needs and opportunities for harmonisation.

This deliverable presents the results of this collaborative analysis and provides a comprehensive overview of the current state of classification, composition identification, sorting and labelling systems for textile waste. It identifies the main gaps and needs emerging from stakeholder engagement activities and translates them into practical recommendations and requirements that will support subsequent project activities, including the development of coding systems, EPR implementation strategies, eco-modulation criteria and future harmonised methodologies for textile waste management.

The findings of this report contribute directly to the broader objectives of Circula-TEX by supporting:

- improved quality and efficiency of textile waste collection and sorting systems;
- enhanced traceability and material identification;
- development of harmonised classification approaches for non-reusable textile streams;
- alignment between sorting outputs and recycling requirements;
- creation of enabling conditions for effective and scalable EPR schemes across Europe.

Ultimately, the work carried out under Task T1.3 contributes to the establishment of a more transparent, interoperable and circular textile ecosystem, capable of increasing material recovery, reducing waste generation and supporting the transition towards a resource-efficient European textile sector.

4. METHODOLOGY

The adopted methodology is based on a structured, iterative, and multi-actor co-creation approach, in line with the principles of participatory research and quadruple helix innovation (involving industry, institutions, research, and civil society). This approach was designed to ensure the collection of robust and representative qualitative evidence across the entire textile value chain, supporting the achievement of the objectives of WP1 and providing a solid basis for the development of the final recommendations included in WP6 of the project.

The methodological design integrates several consolidated frameworks:

- **Stakeholder Theory** (Freeman, 1984), for the identification and classification of relevant stakeholders; Managerial perceptions of stakeholder salience in mining - ScienceDirect
- **Stakeholder Salience Model** (Mitchell et al., 1997), for prioritization based on power, legitimacy and urgency;
- **Qualitative Research Design** (Creswell, 2013for the systematic collection and analysis of qualitative data;
- **Grounded Theory approach** (Glaser & Strauss, 1967), for the inductive emergence of themes and patterns from the collected data;
- **Thematic analysis,** Braun & Clarke (2006), as the primary method for analyzing qualitative data; Using thematic analysis in psychology | Request PDF
- **Snowball Sampling** (Goodman, 1961), for the progressive expansion of the stakeholder network.

The process was divided into two main phases:

1. **Consolidation of the co-creation and stakeholder engagement strategy**: An engagement strategy based on stakeholder mapping techniques was developed, aimed at ensuring representativeness of the entire extended textile life cycle (collection, sorting, repair, reuse, remanufacturing, and recycling). Stakeholders were classified by role, expertise, and relevance to the topics being analyzed, with reference to classification systems, composition identification, sorting, and labelling.
2. **Identification of needs, critical issues and technological gaps**: Data collection was conducted through a collaborative qualitative approach, based on semi-structured interviews developed from an interview guide (questionnaire) developed during the initial phase of the project. The guide was developed iteratively, incorporating contributions from within the consortium and reflecting the main areas of investigation, including classification methods, material composition identification, sorting systems, and labelling.

The interviews were designed to ensure comparability between stakeholders and exploratory flexibility, allowing interviewees to delve into specific aspects based on their experience and role in the supply chain.

Qualitative data analysis was conducted using a thematic analysis approach according to Braun & Clarke's (2006) framework, used as the primary method for identifying, analyzing, and interpreting emerging themes. Specifically, the analytical process followed the method's key phases:

- familiarization with the data through iterative reading of the transcripts;

- generation of initial codes (open coding: in which data (texts, interviews) are fragmented, examined and labelled with concepts (codes) without predefined categories);
- construction and aggregation of themes;
- review and refinement of themes;
- structured analysis of critical issues (gaps), requirements and potential solutions, with particular attention to opportunities for improvement of the explored themes.

The analysis was conducted using a hybrid deductive-inductive approach: on the one hand, the initial themes reflected the areas of investigation defined in the interview guide; on the other, an analytical openness was maintained to the emergence of new patterns directly from the data. This allowed us to identify both expected elements and unexpected emerging findings.

The process was further strengthened through collaborative qualitative analysis elements, including the comparison of perspectives from different stakeholder groups along the textile supply chain. This allowed us to systematically identify needs, operational criticalities, and technological gaps at different stages of the product life cycle.

This approach ensured transparency, consistency, and traceability in the interpretative process, helping to strengthen the methodological robustness and validity of the results.

The entire process was characterized by an iterative and adaptive approach, typical of action research models, in which intermediate results fed into subsequent phases, allowing for a progressive refinement of both the selection of stakeholders and the research topics.

4.1 PROCESS AND TOOLS

Based on the defined methodology, stakeholders were identified and prioritized according to their relevance to the topics under analysis.

Data collection activities were primarily based on:

- semi-structured interviews, conducted one-on-one;
- online meetings via Microsoft Teams;
- recording and transcription of interviews, to ensure traceability and accuracy in the analysis.

The interviews were designed to systematically explore:

- existing methods and practices for classifying and identifying materials;
- sorting and labelling systems;
- operational and technological issues;
- opportunities for improvement from a circular economy perspective.

The process was complemented by:

- qualitative analysis of interview content;
- comparison between stakeholders from different stages of the supply chain (collaborative analysis);
- progressive updating of the stakeholder list through referral mechanisms.

Finally, follow-up and monitoring activities were planned, aimed at:

- verifying the consistency of the information collected;
- update any findings emerging in subsequent phases;
- ensure alignment with the project objectives and related work packages.

The operational tools and processes have helped to consolidate the reliability of the data collection and analysis process and, at the same time, to support the production of solid reports for the subsequent phases of the project.

4.2 STAKEHOLDER ENGAGEMENT METHODOLOGY

Stakeholder engagement was designed to ensure an inclusive and progressive process, gathering representative input along the entire textile value chain.

Initial stakeholder identification was conducted through mapping activities. The role of stakeholders in the various phases of the textile life cycle (collection, sorting, repair, reuse, remanufacturing, and recycling) was taken into consideration, as well as their relevance to the topics under analysis, particularly classification, composition identification, sorting systems, and labelling.

Stakeholders were selected and prioritized together with the project partners, taking into account their ability to significantly contribute to the topics under investigation, ensuring a balance between key players and those with specific expertise.

Initial contact was made via email, generally managed by the WP1 leader (CTB). This facilitated the initiation of dialogue and helped foster a higher level of stakeholder availability and engagement. During the Teams meeting, stakeholders were introduced to the project's objectives without detailing the questions, to encourage spontaneous responses, free from prior preparation.

Engagement was achieved primarily through semi-structured interviews (questionnaires), designed to ensure comparability of the information collected while also allowing for flexibility in exploring the specificities of the various stakeholders. The questions were adapted to the interviewee's profile, calibrating the level of detail and focus of the topics covered based on their role, skills, and position in the supply chain. This fostered greater engagement and the collection of contributions.

Interviews were also conducted with project partners to integrate internal perspectives within the consortium and strengthen alignment with the objectives of WP1. In this context, an online co-creation workshop was organized, involving the project's technical and operational partners. The activity aimed to improve the quality and efficiency of textile waste collection and sorting practices, with particular attention to existing critical issues, operational gaps, and the identification of shared solutions. The workshop also provided an in-depth analysis of various sorting methods, focusing on those that can improve the homogeneity of textile waste flows and facilitate subsequent treatment and recycling processes. Attention was paid to material identification methods, labelling systems, and classification systems, assessing their applicability and the main challenges related to recyclability. Direct dialogue with supply chain operators was a key element of the co-creation process, and the resulting findings served as input for subsequent project activities.

In line with the co-creation approach, stakeholders were involved, and at the end of each interview, interviewees were asked to suggest additional relevant stakeholders, allowing for the integration of new perspectives and reducing the risk of excluding key stakeholders.

Overall, the stakeholder engagement process has allowed us to build a solid information base by identifying needs, critical issues, and opportunities along the textile supply chain and contributing to the development of subsequent project activities.

Table1 - Stakeholder Engagement Process

Phase	Activity	Description	Outcome
Stakeholder Mapping	Identification	Mapping of stakeholders across the textile value chain (collection à recycling) and relevance to key topics	Initial stakeholder pool (internal and external)
Selection & Prioritization	Screening	Selection with project partners based on expertise, role, and contribution potential	Balanced and representative group
Initial Contact	Awareness raising	Email contact (WP1 leader – CTB) to initiate dialogue and engagement	Stakeholder availability confirmed
Engagement Setup	Introduction	Introductory Teams meetings presenting project objectives (no prior questions shared)	Spontaneous and unbiased participation
Data Collection	Interviews	Semi-structured interviews tailored to stakeholder profiles	Comparable yet flexible data collection
Adaptive Approach	Customization	Adjustment of questions based on role, expertise, and position in the value chain	Higher quality and relevance of inputs
Co-creation	Growth effect	Stakeholders suggest additional relevant actors	Expansion of stakeholder network
Consolidation	Analysis	Identification of needs, challenges, and opportunities	Solid knowledge base for project development

4.3 DATA COLLECTION AND ANALYSIS

Data collection was conducted through semi-structured interviews, recorded (with the interviewees' consent) and subsequently transcribed in full. The transcripts were archived in digital format to ensure traceability, accessibility, and consistency in analysis.

The data processing process included an initial support phase using artificial intelligence tools (ChatGPT), used to facilitate activities such as preliminary content synthesis, information organization, and identification of recurring elements. All generated results were subsequently reviewed and validated by the research team to ensure accuracy, interpretative consistency, and alignment with the project context.

Data analysis was conducted using a qualitative approach, based on:

- the identification of recurring themes,
- critical issues,
- emerging patterns along the textile supply chain.

In parallel, an aggregate reprocessing of the responses was performed to identify common trends and provide a concise representation, including quantitative information, of the key findings.

This combined approach allowed us to integrate the depth of qualitative analysis with elements of quantitative synthesis, improving the readability of the results and supporting the identification of shared priorities among stakeholders.

Overall, the data collection and analysis process ensured a high level of consistency, transparency, and robustness, contributing to the production of reliable evidence to support subsequent project phases.

4.4 LIMITATIONS

The operational approach adopted for data collection and analysis is consistent with the co-creation approach defined in the first deliverables (D1.1). In outlining this data collection and analysis process, some limitations were highlighted, partly intrinsic to the qualitative nature of the study. Therefore, although the approach adopted was designed to ensure robustness and representativeness, some critical issues emerged; however, these were mitigated through specific methodological choices that strengthened the reliability and consistency of the results.

A first limitation concerns the selection and number of stakeholders involved. Although the sample includes actors representing the various stages of the textile supply chain and the topics investigated, it cannot be considered exhaustive. In complex, multi-actor contexts, some perspectives may not have been fully captured, or additional relevant stakeholders may not have been included in the collaborative analysis process.

However, this criticality was significantly mitigated through an iterative approach to network expansion, which allowed for the progressive integration of new actors and strengthened the overall coverage of the collected perspectives.

Mitigating the Limitation: Stakeholder Exhaustiveness

The criticality of the sample's inexhaustibility was mitigated through:

- an iterative stakeholder engagement approach, which involved progressively expanding the network over the course of the process;
- the systematic adoption of referral mechanisms, asking each interviewee to identify additional relevant stakeholders;
- initial stakeholder mapping and segmentation to ensure coverage of the various stages of the textile supply chain;
- the involvement of stakeholders from diverse categories to include complementary perspectives;
- follow-up activities, which allow for the integration or clarification of contributions emerging in subsequent phases.

A second limitation is related to the heterogeneity of stakeholder profiles, which leads to intrinsic variability in the responses provided. The evidence collected is strongly influenced by role, expertise, and position along the supply chain, making it difficult to develop unambiguous summaries or define representative "average" values. Rather than being considered a weakness, this variability was interpreted as a relevant piece of information and leveraged through a comparative approach, allowing for a more nuanced and systemic understanding of the issues analyzed.

Mitigating the Limitation: variability of contributions:

The critical issue related to the variability of contributions was managed through:

- the use of a semi-structured interview guide, which ensured consistency and comparability across interviews;

- the adaptation of questions based on the stakeholder profile, to obtain more relevant and targeted contributions;
- a comparative analysis approach between stakeholders, which allowed differences to be interpreted as informative elements;
- the application of perspective triangulation, comparing responses from different stakeholders along the supply chain;
- the adoption of thematic analysis, which allows for the identification of cross-cutting patterns even in the presence of heterogeneous data;
- the integration of aggregate summaries, useful for highlighting common trends without forcing an artificial average.

Overall, these methodological measures have effectively mitigated the main critical issues, ensuring a high level of robustness and consistency in the data analysis and interpretation process.

5. REGULATORY FRAMEWORK AND EPR ALIGNMENT

5.1 WHY CLASSIFICATION AND SORTING ARE BECOMING STRATEGIC

The transition towards a circular textile economy is progressively transforming classification, composition identification, sorting and labelling from operational activities into strategic enablers of textile circularity. Historically, textile waste management in Europe has been primarily driven by reuse markets and by the economic value of second-hand clothing. Consequently, classification and sorting systems evolved mainly to support resale and export activities, with limited attention to recycling requirements.

This context is rapidly changing. A combination of new regulatory obligations, increasing waste volumes, growing demand for recycled materials and emerging traceability requirements is creating unprecedented pressure to improve the quality, transparency and efficiency of textile waste management systems. As a result, classification and sorting are becoming critical functions for achieving the objectives of the European Green Deal, the EU Strategy for Sustainable and Circular Textiles and the emerging Extended Producer Responsibility (EPR) framework for textiles.

Mandatory separate collection and increasing waste volumes

One of the most significant drivers of change is the obligation introduced by the Waste Framework Directive requiring Member States to establish separate collection systems for textiles from 2025 onwards. This measure is expected to substantially increase the amount of textile waste entering dedicated collection streams and subsequently requiring classification, sorting, reuse assessment and recycling preparation.

The implementation of separate collection represents a fundamental step towards diverting textiles from landfill and incineration. However, collection alone does not guarantee circularity. The environmental and economic value of collected textiles depends largely on the ability to correctly identify, classify and sort materials according to their most suitable end-of-life destination.

At the same time, textile consumption in Europe continues to generate large volumes of waste. The growing diversity of textile products, including fibre blends, coated materials, technical textiles and multi-material constructions, further increases the complexity of waste management operations. Consequently, sorting infrastructures originally developed for reuse-oriented markets are increasingly being asked to support recycling-oriented objectives for which they were not originally designed.

This transition is creating significant operational challenges throughout the value chain. Collection systems are expected to handle larger volumes, while sorting operators must distinguish between reusable products, recyclable materials and residual fractions with increasing accuracy. Without improvements in classification and sorting methodologies, the expected increase in separately collected textile waste could generate bottlenecks that limit the effectiveness of future circular systems.

Limitations of current sorting systems

Current textile sorting practices remain highly fragmented across Europe. In many cases, classification criteria have evolved according to local market conditions, historical reuse channels and company-specific operational needs rather than according to harmonised recycling requirements.

Manual sorting remains the dominant approach, particularly for assessing product quality, condition and reuse potential. Human expertise is often capable of evaluating factors that remain difficult to automate, such as wear, defects, fashion relevance and resale value. However, manual sorting alone is increasingly insufficient to support large-scale recycling systems requiring detailed and reliable information about material composition.

Automated technologies based on Near Infrared Spectroscopy (NIR), hyperspectral imaging, artificial intelligence and optical recognition systems have significantly improved in recent years and are already capable of identifying major fibre categories at industrial scale. Nevertheless, important limitations remain. Current technologies often struggle with low-percentage fibre blends, elastane-containing products, dark-coloured textiles, multilayer constructions, hidden components, coatings and chemical treatments.

Furthermore, the categories currently used by many sorting operators do not always correspond to the requirements of downstream recycling technologies. Materials that appear similar from a product perspective may have very different suitability for mechanical recycling, chemical recycling, reuse or alternative recovery routes. This mismatch highlights the need for more harmonised classification approaches capable of connecting upstream sorting decisions with downstream processing requirements.

The growing importance of feedstock quality for textile-to-textile recycling

The emergence of textile-to-textile recycling represents another major factor increasing the strategic importance of classification and sorting. Both mechanical and chemical recycling technologies require feedstock streams with defined characteristics regarding fibre composition, contamination levels, colour, additives and physical properties.

For many recycling technologies, feedstock quality has become one of the main determinants of process efficiency, product quality and economic viability. Even small variations in material composition can significantly affect recycling performance and the quality of the resulting secondary raw materials.

This situation creates a fundamental shift in the role of sorting systems. Rather than simply separating reusable from non-reusable products, future sorting infrastructures will increasingly be required to generate material fractions tailored to specific recycling pathways. Consequently, classification systems must evolve from generic product-based categories towards more detailed descriptions of material characteristics, structural complexity and recycling compatibility.

Several stakeholders consulted during Task T1.3 highlighted that sorting categories should be driven not only by fibre composition but also by the requirements of the intended downstream process. From this perspective, classification becomes a strategic interface between waste generation and material recovery, directly influencing the feasibility of high-value circular business models.

Traceability, Digital Product Passports and future policy requirements

Alongside physical sorting challenges, the textile sector is also experiencing a significant transformation in information management and product traceability. The Ecodesign for Sustainable Products Regulation (ESPR) and the future implementation of Digital Product Passports (DPPs) are expected to substantially increase the availability of product-related information throughout the lifecycle.

The Digital Product Passport is intended to provide structured information on product composition, materials, manufacturing characteristics, repairability, recyclability and environmental performance. For classification and sorting systems, access to reliable product data could significantly improve the identification of textile waste streams and support more accurate separation of materials.

However, stakeholders consistently emphasise that information alone will not solve existing sorting challenges. Product data must be integrated with physical identification technologies, operational sorting procedures and harmonised classification frameworks. In practice, Digital Product Passports should be viewed as one component of a broader ecosystem combining traceability, labelling, automated identification systems and recycling-oriented classification methodologies.

The increasing convergence between ESPR requirements, Digital Product Passports, EPR schemes and recycling targets suggests that classification and sorting will play a central role in future textile circularity policies. Effective implementation of these policies will depend not only on the availability of technological solutions, but also on the development of shared standards, common data structures and interoperable classification systems capable of supporting actors across the entire textile value chain.

Implications for Circula-TEX

Within this evolving regulatory and industrial landscape, the analysis conducted in Task T1.3 becomes particularly relevant. Understanding current practices, technological limitations, stakeholder requirements and opportunities for harmonisation is essential for supporting the development of future classification systems, coding architectures, EPR implementation mechanisms and Digital Product Passport applications.

The findings presented in this deliverable therefore contribute to a broader strategic objective: enabling the transition from fragmented and market-specific sorting practices towards a harmonised European framework capable of supporting high-quality reuse, efficient recycling and scalable circular textile value chains.

5.2 RELEVANT EU LEGISLATION

Eu legislation on separate collection of textile waste and sorting

While the term "waste sorting" itself is not explicitly defined in the Waste Framework Directive (Directive 2008/98/EC), the directive emphasizes the importance of separate collection systems. Under the Waste Framework Directive (WFD), Member States are required to set up separate collection of textiles by 2025. Sorting is then one of the main objectives of this policy, together with collection, reuse, preparation for reuse and recycling.

Figure 1 Waste Hierarchy Diagram – European Commission

Within this framework, sorting represents a key enabling step between collection and downstream treatment options such as reuse, preparation for reuse and recycling. Effective sorting is therefore essential to ensure the quality and traceability of textile fractions and to maximize their circular value.

However, current implementation across Member States remains heterogeneous, particularly in terms of sorting infrastructure, classification criteria and data standardization, which directly affects the efficiency of downstream circular processes.

Eu legislation on labelling

The EU regulatory framework recognises the increasing importance of accurate fibre identification, driven by the emergence of new textile fibres and the growing complexity of recycling technologies. Regulation (EU) 1007/2011 on textile fibre names and related labelling requirements is currently under revision.

The European Commission is assessing the introduction of a harmonised and more comprehensive labelling system for textile products, including the potential integration of environmentally relevant information to support circularity, transparency and recyclability. The adoption of the revised framework is currently planned for Q3 2025.

Improved labelling is considered a key enabler for more effective sorting, automated identification systems and high-quality recycling streams.

5.3 ALIGNMENT WITH EMERGING EPR REQUIREMENTS

The harmonised Extended Producer Responsibility (EPR) regulations for textiles, proposed by the European Commission, as a part of the WFD (2023), aims to establish an economy focused on collecting, sorting, reusing and recycling textiles, while also ensuring that products are designed with circularity in mind.

Standardization of classification procedures of textile waste is fundamental for subsequent phases of value chain (collection and sorting, recycling, reusing), for supporting the creation of a market for SRM, facilitate identification and labelling of products and promoting the development of a circular textile environment.

Averagely 12% of post-consumer textile waste is collected separately for reuse or recycling, while the remained is often incinerated or landfilled[1].

Discarded used clothing is generally collected by commercial actors, charity shops, brands and retailers though collection points and clothes bins.

Most of collected textiles (65% are garments) are sorted within Europe, but 35% are exported outside EU.

[1] ETC Report, 2023

6. OVERVIEW OF METHODS FOR CLASSIFICATION, COMPOSITION IDENTIFICATION, SORTING AND LABELLING (STATE OF THE ART)

6.1 CLASSIFICATION METHODS

The classification of textile[2] products is a crucial step in distinguishing between items considered waste and potentially reusable goods. This distinction is essential for determining the correct management path along the supply chain, influencing the subsequent stages of collection, sorting, reuse, and recycling.

A comprehensive overview of classification methods was developed as part of Task 4.1 of the Circula-TEX project and is described in Deliverable 4.1. In summary, the methods analyzed are based on a combination of visual, functional, and qualitative criteria, which allow for the assessment of the product's condition, its reuse potential, and its suitability for recovery processes.

However, the analysis highlighted significant heterogeneity in currently adopted classification practices, often characterized by a high degree of subjectivity and limited standardization. This aspect represents a major critical issue for the overall efficiency of the supply chain and the quality of the flows destined for reuse and recycling.

Effective classification therefore plays a key role in the circularity of the textile sector, as it:

- ensures proper management of flows, in line with the European Union waste hierarchy;
- prevents contamination between materials, improving the quality of flows destined for reuse and recycling;
- facilitates sorting operations and subsequent treatment phases;
- contributes to the traceability of materials along the supply chain.

In the context of the project, improving classification methods is closely linked to the development of more effective labelling systems and the adoption of shared approaches among supply chain stakeholders, in order to reduce ambiguity and support more efficient and circular management of textile waste.

6.2 COMPOSITION IDENTIFICATION METHODS AND SORTING SYSTEMS

Correct identification and sorting of textile waste are essential steps to ensure effective management of flows and enable recovery processes consistent with the principles of the circular economy. Specifically, these activities play a key role in determining the quality and destination of materials along the supply chain, directly impacting reuse and recycling opportunities.

Correct identification and sorting are fundamental for circularity transition because they

- Allow efficient and targeted recycling (correct technology) of homogeneous materials
- Improve efficiency and quality of SRM (market)
- Ensure removal of non-recyclable elements

[2] *EEA,Management of used and waste textile in Europe's circular economy*

- Ensure only high-quality textile go to reuse markets
- Reduce downcycling or incineration due to poor sorting efficiency and accuracy (EU goals)

Nowadays, identification and sorting of waste textiles is strongly dependent on the facility (geographic location, technologies, investments, automatization, scope, sales channels) and on the demand (volume of textiles). For these reasons, despite textile waste sorting is one of the key aspects in waste valorization, up to now it is still an unstandardized process.

In particular, in Europe, charity and no-profit organisations are actually the main actors involved in the collection of used textiles, where textiles are sorted into different qualities which are usually directed to different markets for re-use[3]. Among the biggest plants are TEXAID based in Switzerland, Trasborg in Denmark, SOEX in Germany. However, they usually do not address sorting of textile material for recycling outside the portion of collected textiles that is not suitable for re-use and that is sold as unsorted stream to other countries/actors.

Textiles for recycling need to have a known fibre composition, because of the requirements and limitations of fibre composition used as input for recycling processes[4]. While automated sorting is still at preliminary stage (<1% of post-consumer textiles are subject to automated sorting[5]), it is clear that for increasing amount of collected textile waste and high-quality sorting for recycling, it will become complementary technique to manual sorting. At the same time, manual sorting might remain highly relevant to evaluate textile quality, particularly when assessing re-use potential for client markets.

There are few existing facilities that are now the benchmark for automated textile sorting for recycling, addressing the composition of waste, as for example Coleo Recycling[6] textile facility, Spain, with a current capacity of 2 200 tonnes per year, relying on NIR and Artificial Intelligence techniques.

Moreover, Siptex[7] is an automatic textile sorting facility in Malmö, Sweden, using NIR and VIS spectroscopy for sorting textiles according to colour and composition, with a maximum sorting capacity of 24 000 tonnes per year.

Also, technology providers for manual, semi-automatic and integrated sorting systems for textile waste based on NIR technology are emerging (e.g. Fibersort[8]).

Spectroscopy is the most promising technology, measuring the interaction between light and matter (in this case textile waste). The most common and effective spectroscopic approach works with Near InfraRed light (NIR)[9]. Through the measurement of a NIR absorption spectrum,

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[3] Köhler, A., Watson, D., Trzepacz, S., Löw, C., Liu, R., Danneck, J., Konstantas, A., Donatello, S., Faraca, G., 2021. Circular Economy Perspectives in the EU Textile sector, EUR 30734 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-38646-9, doi:10.2760/858144, JRC125110.

[4] Watson, D., Trzepacz, S., Lander Svendsen, N., Wittus Skottfelt, S., Kiørboe, N., Elander, M., Nordin, L.., 2020b. Towards 2025: Separate collection and treatment of textiles in six EU countries, Miljøstyrelsen.

[5] Huygens, D., Foschi, J., Caro, D., Caldeira, C., Faraca, G., Foster, G., Solis, M., Marschinski, R., Napolano, L., Fruergaard Astrup, T. and Tonini, D., *Techno-scientific assessment of the management options for used and waste textiles in the European Union.* Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/6292, JRC134586.

[6] https://coleo.es/recycling/

[7] https://smartcitysweden.com/best-practice/415/siptex-groundbreaking-textile-sorting/

[8] https://www.fibersort.com/

[9] Dahlbom, M., Aguilar Johansson, I., Billstein, T., 2023. Sustainable clothing futures - Mapping of textile actors in sorting and recycling of textiles in Europe, Swedish Environmental Research Institute (IVL). Report number C736

the technique allows to detect chemical features of the samples under examination, such as fiber composition or also the presence of surface finishes, coatings, and contamination.

The analysis of the collected spectra enables to discern categories such as pure material (100 % cotton, 100% polyester etc), mix of material (40/60% cotton/polyester) or material families (cellulosic fibres, polyamides).

In particular, these complex spectroscopic data are analyzed with special software using mathematical-statistical models to construct an analysis method, using this discipline called chemometrics (i.e. mathematical analysis of chemical data). These methods allow us to predict the composition of a fabric sample by comparing it with a library of known samples, previously acquired and validated.

At present, NIR spectroscopy is applied as a tool during process analytical technology (PAT) and quality control (QC) as the method of choice in various fields, i.e. agriculture, food, bioactives, pharmaceuticals, petrochemicals, cosmetics, chemicals and of course textiles[10].

NIR spectroscopy, in comparison with most other analytical (e.g. GC and HPLC) and conventional chemical (e.g. Kjeldahl, Soxhlet) methods, is rapid, chemical-free, easy to use (once calibrations have been developed) and non-destructive. Although the accuracy of the NIR method strongly depends on the accuracy and precision of the reference method, NIR measurements and predictions are considered more reproducible. Furthermore, it does not require sample preparation and it is non-destructive.

The main disadvantage is that, as it is a statistical analysis, a large number of known samples are required to build the library in order to have a good reliability of the prediction. On the other hand, since spectra are collected within an area and collected data are expressed as a mean spectrum, the information on spatial distribution of constituents within the sample is thus lost.

The development of NIR hyperspectral imaging, which combines NIR spectroscopy with digital imaging, enables both spatial (localization) and spectral (identification) information to be obtained simultaneously, making possible to describe distribution of constituents within a sample.

The use of NIR hyperspectral imaging has been investigated extensively to determine the quality and safety of agricultural and food products, finding additional application in medicine, paleontology, and archaeology.

From a practical point of view, the hyperspectral imaging setup usually requires more expensive equipment with respect to NIR spectrometer, external illumination source, longer acquisition times for high-quality image, longer time of analysis due to heavy digital data[11].

Another challenging aspect of post-consumer recycling is the chemical safety of waste textiles. Several substances used in the textile industry can bring environmental or health problems[12].

To face the chemical safety issue, several companies have adopted voluntary certifications, such as the OEKO-TEX® certifications[13] or have adhered to chemical management protocols such as ZDHC, in order to guarantee safety for the end user.

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[10] E. Cleve, E. Bach and E. Schollmeyer, Anal. Chim. Acta, 2000, 420, 163–167.
[11] *Chem. Soc. Rev.,* 2014, 43, 8200
[12] Joaquim Rovira, José L. Domingo, Human health risks due to exposure to inorganic and organic chemicals from textiles: A review, Environmental Research, Volume 168, 2019, Pages 62-69, ISSN 0013-9351, *https://doi.org/10.1016/j.envres.2018.09.027*
[13] https://www.oeko-tex.com/en/

Despite these efforts, the delocalization of textile production to countries with fewer environmental restrictions or standards and a more complex life cycle of clothing may threaten the final user and post-consumer recycling. Considering the presence of contaminants in textiles, it is thus relevant during the sorting process.

Nowadays, the analytical techniques used for contaminants detection are based on quantitative tests and often involve extracting substances from the textile matrix using solvents. Once extracted, the substances are separated using chromatographic techniques (Liquid Chromatography, LC, or Gas Chromatography, GC) or induction coupled plasma (ICP). These analyses shall be performed by a well-equipped laboratory, with expensive precision instrumentation and highly skilled technicians. They are generally destructive and require interpretation of the data obtained[14]. The development of new technologies for screening and analyzing contaminated textile materials is an urgent topic because it would reduce time, cost, and the need to operate in specialized laboratories. Although today's validated databases of contaminated textiles and sampling methodologies are still vacant, NIR technology could represent a promising candidate for a fast yet effective screening of contaminants in textile materials.

Finally, NIR spectra and spectra images can also be further processed using Artificial Intelligence (AI) softwares for high-throughput data analysis and for improving the classification and sorting of specific materials (e.g. of a specific shape, textures, apparel and footwear categories, technical textiles and composite materials).

6.3 LABELLING METHODS

Labelling consists of providing information on textile products, particularly on fiber composition and the presence of any non-textile parts of animal origin. This information is essential for the correct identification of materials and for product management throughout their entire life cycle.

In the context of the Circula-TEX project, the concept of labelling is being expanded to a broader dimension, including not only the physical characteristics of the product, but also information related to production processes, environmental impacts, and material traceability. This approach is in line with European regulatory developments, particularly the requirements for the Digital Product Passport (DPP), which aims to improve product transparency and circularity.

An effective labelling system plays a key role in supporting the transition to a circular economy, as it:

- enables greater transparency of product information for consumers, supply chain operators, and recyclers, including in terms of sustainability;
- facilitates accurate material identification, improving the efficiency of sorting and treatment processes;
- Enables the adoption of automated material sorting and identification systems;
- Supports the traceability of flows along the supply chain;

[14] Undas, A. K., Groenen, M., Peters, R. J. B., van Leeuwen, S. P. J., 2023, Safety of recycled plastics and textiles: Review on the detection, identification and safety assessment of contaminants, Chemo-sphere, 312, 137175, https://doi.org/10.1016/j.chemosphere.2022.137175

- Ensures compliance with European regulatory requirements, including those related to the Digital Product Passport (DPP).

However, the analysis highlighted that current labelling systems are often limited and not fully aligned with the needs of recycling processes. In many cases, the available information is incomplete, non-standardized, or difficult to access in operational contexts, hindering the efficiency of textile waste sorting and recovery systems.

In this context, the development of more advanced and integrated labelling solutions is key to improving the quality of material flows, supporting innovation in sorting processes, and facilitating the achievement of the textile sector's circularity goals.

7. CO-CREATIONS ACTIVITIES

7.1 INTERNAL STAKEHOLDERS' WORKSHOP

To kick off the collaboration within the Consortium, the first online Workshop was held in April 2025. The core four main topics to be discussed in the framework of WP1 was then presented, and particularly Sustainable Design for Recycling by RINA, Methods for classification, composition identification, sorting and labelling systems by COT; Reuse, repair, redistribute, refurbish and remanufacture by NTT; and EPR role by CTB.

Then, participants in the call were divided into four different breakout rooms. In each of them, the task leader encouraged a friendly discussion about the SWOT aspects of each previously presented topic. The answers were collected in a share board, and the raw answers are reported in the following four sub-paragraphs. After reporting the responses exactly as they were provided during the workshop, the main points that emerged for each of them were subsequently summarized.

Table2 – Questions for internal stakeholders

Pillar 1	Pillar 3
STRENGHTS	From your point of view, **which are the strengths** in collection, classification, composition identification, sorting, and labelling of textile waste? Can you provide the best cases and practical examples?
WEAKNESSES	From your perspective, **why** classification, composition identification, sorting and labelling **are still unclear and unstandardized** in textile sector? Which are the limitations to the development of efficient sorting?
OPPORTUNITIES	What would be the strategies for finding standardized methodology? What **trends, external actions or opportunities can help** acceleration of this process? Please provide examples of technologies, emerging fields, etc.
THREATS	Which **barriers do you think could slow down** the application of efficient classification, composition identification, sorting and labelling? (Do you think that the main obstacles will be overcome in the future?)

Table3: Strengths identified during the internal Workshop

Strengths

- Collaboration with recycling tech experts
- Creating a pull effect
- Design for longevity, repair and re-use are quite clear to implement
- Design for recycling can improve sustainability by mandating that different materials in a product are easily separated
- Developed infrastructure
- Enhanced product recyclability and material recovery
- Established mechanical recycling line

- Experience with pre-sorting for recyclability criteria
- Extensive experience and know-how
- Facilitation of closed-loop textile recycling systems
- Focus on innovation and sustainability
- Growing awareness among brand/SMEs companies for integrating R principles into textile products
- High processing capacity
- If Ecodesign properly implemented, it can increase number of recycled sources in the market, therefore increase demand and number of recyclers
- increase in high quality feedstock for t2t recycling
- Increased availability of Mono materials textile
- Innovation
- Knowledge of textile composition and recyclability
- Making products easy dismantlable
- Material compatibility insight, lifecycle thinking from scratch
- Membership in professional networks
- Optimization of resources
- Reduction of waste and landfill dependency
- Regulatory support and incentives more available
- Stakeholder role in EU-level discussions
- Textile manufacturers provide uniform post-industrial waste to use for recycling
- The cultural migration towards more sustainable choices, making consumers to buy according to different choices
- The use of mono materials
- Waste reduction

Table4: Weaknesses identified during the internal Workshop

Weaknesses

- Challenges with complex blend and multi-materials
- Current lack of harmonized recycling
- D4R needs harmonization rules
- Dependent on technologies to recycle materials, which are constantly evolving, requires constant updating
- Design for recycling is not yet standardized and limits the 'freedom of design' for designers and product developers
- Difficulty to reach the product quality and durability for many fashion business models actually

- Educate manufacturers and define exactly what waste is or ready for reuse. Any alternatives to zippers that could be recycled? Lack of R&D on the topic
- High R&D costs for new recyclable materials
- Insufficient effort in designing products using BAT recycled materials. It seems everyone is waiting for the perfect material to substitute 1to1 virgin materials for the same original applications. This is a cultural bias
- Issue with companies sitting outside of Europe, how will this be controlled, audited and monitored? -> important to not allow loopholes (Such as the issue we have today with the imports from China which don't have to pay any custom)
- Lack of practical knowledge in applying DfR principles
- Lack of scalable collaboration models with brands/designers
- Limited knowledge and expertise in recyclable textile design
- Limited recycling infrastructure and economic barrier since recycled fibers can be more expensive or low quality
- limited scalable solutions. SUPPLY CHAIN RESISTANCE. Lack of standardized design for recycling metrics. High cost of innovation.
- Limited traceability/data on textile inputs
- Market saturation risk > low quality garments can flood reuse markets
- Need integration with other company function to be harmonized, almost it shall be on a dialogue with strategic development
- No direct control over product design
- The current paradigm in clothing purchase/consumption limits the possibility of application DfR in terms, for example, of materials
- This approach clashes with the way the industry currently develops products
- Trade-offs between recyclability and product performance
- Until now it was more voluntary with the ESPR hopefully this becomes more tangible
- Value chain complexity

Table5: Opportunities identified during the internal Workshop

Opportunities

- Advanced technologies for separation of material blends and disassembly of textile products
- AI systems, technologies to facilitate sorting and tracking processes
- Clear labelling & traceability
- Could be connected to different destinations (thinking about of a category of good designed to be recycled with different technologies for different applications) So it could open for diversification and several niche markets
- design with recycled content, but there is still little recycled content available in the market

- Increasing awareness of the environmental impact of textiles (e.g. for fast fashion, ultra-fast fashion, poor quality etc.)
- It could be helpful for brand reputation
- It could be integrated into sustainability approaches of an organization
- It could help maximize the circularity of materials and give a long span life to materials, decreasing environmental impacts and costs
- It could lead to job creation (the same material will be processed several times)
- It could open to new SBM (for instance a company could implement a take back business model thanks also to D4R)
- Legislations ESPR
- New materials development (bio-based, mono-material)
- New training programs incorporates the new Design for recycling principles
- Textile to textile recycling advancements. DPP synergy. Brand circularity commitments. Innovation for detachable components and mono materials.
- The demand of consumers for transparency and more attention to production sustainability.
- to start offering honest and transparent products made of recycled materials to create cash flow to be reinvested in innovation
- Via eco modulations and eco design, there is power to change the whole manufacturing process of a company because it is too costly to be non-compliant and cost-effective to produce durable/recyclable products

Table6: Threats identified during the internal Workshop

Threats
• Competitive disadvantage if recyclability increases costs significantly • Competitiveness of cheaper recycled feedstock from outside of Europe which helps brands meet the targets but doesn't help the European waste problem and collection, sorting and recycling infrastructure. • Competitiveness of European companies versus cheap clothing from abroad --> we need to start thinking of VAT structures/Gate fees/etc. • Consumer misunderstanding of design for recycling value. • Consumer reluctance if recyclable products are perceived as lower quality • Design for recycling may conflict with requirements for higher durability and functional-ity/comfort. • Different legislation all over Europe and all over the world • fragmented industry adoption. • Lack of competitivity if European garments are aligned with DfR principles while gar-ments from Asian region are not • Lack of consumer response if the recycled product is not on par with the virgin quality (look & feel) the consumer is used to or even requiring • Lag in recycling infrastructure capable of handling new D4R products • Lower consumers awareness and low interest in sustainability claims • Market pressure for fast design turnarounds. • Misalignment across value chain. • No direct economic incentive for brands • Other geographical areas are starting to offer recycled fibers/products that will dominate the EU market if the regulation slows starting of the circular business • Rapidly changing material and recycling technologies create design uncertainty • Regulations to create overly demanding specifications that will practically impede the creation of an offer of recycled products waiting for the 'perfect solutions' • Risk of greenwashing • Risk of higher prices for products which are aligned to DfR principles • Technological immaturity (e.g. high costs for recycling technologies);

The raw inputs collected through the SWOT analysis were subsequently reviewed and overlapping and recurring concepts were clustered to reduce redundancy, while related insights were grouped according to common drivers and impacts. The resulting insights were then structured into coherent thematic areas (Financial, Environmental, Corporate, and Market) as shown in the following tables. This approach allowed for a clearer, more structured interpretation of the overall results.

Table7: Synthesis of Identified Strengths

Financial	Higher availability of quality recycled feedstock Strong market pull and growing demand for recycling solutions Efficient recycling capacity supported by established infrastructure Resource efficiency and reduced waste management costs
Environmental	Enhanced material recyclability through mono-materials and design for disassembly Support for closed-loop textile recycling and improved material recovery Reduced waste generation and lower landfill dependency driven by lifecycle-based design
Corporate	Strong technical expertise and collaborations with recycling technology experts Clear strategic focus on innovation and sustainability Active engagement in professional networks and EU-level policy discussions
Market	Growing awareness among brands and SMEs on circular design Cultural shift toward more sustainable consumer choices Increasing regulatory support and incentives Clear implementation of design for durability, repair, and reuse

Table8: Synthesis of Identified Weaknesses

Financial	High costs of R&D and innovation for recyclable materials and components Economic barriers linked to recycled fibers (higher costs, variable quality) Limited scalability of solutions
Environmental	Difficulty recycling complex blends and multi-material products Trade-offs between recyclability, durability, quality, and product performance Dependence on evolving recycling technologies and limited availability of BAT recycled materials and recyclable components
Corporate	Lack of harmonized Design for Recycling rules, standards, and metrics Limited expertise and constrained design freedom in applying non-standardized DfR approaches Weak cross-functional integration and limited control over product design Value chain complexity, supply chain resistance, and limited traceability Lack of scalable collaboration models with brands and designers
Market	Cultural preference for virgin material over redesign for recyclability Misalignment between DfR principles and current fashion consumption and development models Limited education and clarity on recyclable vs. reusable waste Challenges in enforcement, monitoring, and alignment beyond the EU market

	Historically voluntary nature of DfR, with still-emerging regulatory clarity

Table9: Synthesis of Identified Opportunities

Financial	New revenue streams and cost savings driven by ecodesign and eco-modulation Investment and job creation linked to circular and recycled products
Environmental	Increased material circularity and extended material lifespan Reduced environmental impacts and lifecycle costs through Design for Recycling and advanced separation and disassembly technologies Advancement of textile-to-textile recycling and mono-material solutions
Corporate	Integration of Design for Recycling into corporate sustainability strategies Development of new sustainable business models (e.g. take-back systems) Innovation driven by new materials, AI-based sorting, traceability, and DPP Upskilling through new training programs aligned with DfR principles Strengthened governance and compliance driven by ESPR requirements
Market	Growing consumer demand for transparency and sustainable textile products Enhanced brand reputation through credible circularity and recyclability claims Market diversification enabled by products designed for multiple recycling destinations Increasing availability and market uptake of recycled-content products

Table10: Synthesis of Identified Threats

Financial	Higher production costs and prices may reduce competitiveness of DfR-aligned products Lack of direct economic incentives and competition from cheaper non-EU products
Environmental	Lagging or immature recycling infrastructure and technologies Trade-offs between recyclability, durability, comfort, and functionality
Corporate	Fragmented regulations and uneven adoption across regions and value chains Rapid technological changes and uncertain or overly demanding regulatory requirements Risk of greenwashing and misalignment among value-chain actors
Market	Low consumer awareness or trust in recyclability claims Perception of recycled products as lower quality Strong market pressure for fast fashion and rapid design cycles

7.2 External stakeholders' interviews

The external stakeholder interviews constitute the core empirical basis of the T1.3 analysis. The consultation was designed to capture the operational, technological, and strategic views of actors positioned across the textile waste value chain, with a specific focus on collection, classification, composition identification, sorting and labelling. In line with the public dissemination nature of this deliverable, individual participants and companies are treated in anonymized form. The analysis therefore refers to stakeholder groups, value-chain positions and anonymised evidence rather than to individual respondents.

The final analytical matrix used for this section includes 30 completed stakeholder interviews and interview minutes. Two additional mapped stakeholders remained outside the analytical sample because the corresponding detailed transcript or validated minutes were not available at the time of consolidation. The evidence base is therefore broad enough to support a comparative qualitative analysis and sufficiently structured to identify recurrent patterns, divergences and sector-specific needs.

7.3 Stakeholder mapping and engagement strategy

Stakeholders were mapped according to their position in the textile value chain and their expected contribution to the four pillars of Task T1.3. The consultation intentionally included producers, recyclers, sorters, technology developers, research organisations, reuse operators and waste-management companies. This sampling strategy was chosen because classification and sorting are not stand-alone technical operations: their effectiveness depends on product design, collection routes, available recycling technologies, downstream markets, policy incentives and data systems.

The engagement approach was therefore based on value-chain coverage rather than on a single-sector survey logic. This is particularly important for textile waste, where the same material stream may be perceived differently by a brand, a sorter, a mechanical recycler, a chemical recycler, a carpet producer or a waste-treatment operator. For this reason, the sample was deliberately heterogeneous. The heterogeneity is not a weakness of the dataset, but one of the main analytical strengths, because it makes visible the mismatches between upstream decisions and downstream requirements.

Table11 - Anonymised distribution of the analysed stakeholder sample by functional group

Stakeholder group	**Number of interviews**	**Main relevance for T1.3**
Chemical recyclers and material-to-material technology developers	9	Definition of feedstock specifications, impurity tolerance, contamination thresholds and demand for composition data.
Carpet and flooring manufacturers	4	Evidence on multilayer products, mono-/duo-material design, carpet take-back and carpet-specific labelling.
Apparel brands and product owners	3	Influence of design decisions, product information, EPR compliance and supply-chain constraints.

Technology providers, research projects, RTOs and clusters	6	State-of-the-art technologies, pilot systems, standards, testing methods and innovation pathways.
Collectors, sorters, reuse and waste-management operators	4	Operational evidence on collection, manual sorting, reuse markets, non-recyclable fractions and economic bottlenecks.
Mechanical recyclers, spinners and fibre processors	4	Requirements for fibre length, cleanliness, supply stability, colour and mechanical quality.

To preserve anonymity, the analysis does not associate specific statements with named organisations. Instead, stakeholders were grouped by functional role. This approach also makes the analysis more useful for EPR guideline development, because EPR requirements will need to address responsibilities and incentives by actor category rather than by individual company.

7.4 SYNTHESIS OF STAKEHOLDER FEEDBACK

Stakeholder participation was generally high and the interviews produced rich qualitative evidence. Most respondents were willing to share operational barriers, provided that individual statements would not be attributed publicly. This is relevant because many of the most useful insights concerned commercially sensitive topics, including feedstock quality, cost structures, technology limitations, failed pilots, difficult customer expectations and doubts about current EPR approaches.

The consultation confirmed that the textile sector is at a transition point. The collection obligation, EPR discussions, Digital Product Passport requirements, eco-design policies and recycled-content expectations are creating a strong regulatory signal. However, the industrial system is still characterised by fragmented sorting categories, limited automated capacity, weak demand for recycled outputs, uncertainty about feedstock specifications and significant differences between material families.

7.5 STATISTICAL AND ANALYTICAL RELEVANCE OF THE SAMPLE

Although the sample is not statistically representative of the entire European textile sector, it covers the main stakeholder groups directly involved in collection, sorting, recycling, traceability and EPR implementation. Therefore, the results can be considered analytically representative of the current challenges and opportunities associated with textile waste classification and sorting.

The sample should not be interpreted as statistically representative in a strict probabilistic sense, because stakeholders were selected through purposive and snowball sampling rather than random sampling. However, it is statistically and analytically relevant for the objectives of this deliverable for four reasons:

1. the number of interviews is high for a qualitative value-chain study, especially considering the technical depth of the interviews;
2. the sample covers the main actor categories required to understand classification and sorting, including upstream product designers and downstream recyclers;
3. recurrent themes reached a clear level of saturation: the same core barriers appeared repeatedly across different stakeholder categories;
4. the sample includes both convergent and divergent viewpoints, allowing the analysis to distinguish cross-cutting needs from role-specific requirements.

Thematic saturation was particularly evident for the following issues:

- the economic fragility of sorting for recycling,
- the insufficiency of current labels,
- the need for downstream-driven sorting categories,
- the limits of NIR for multilayer or low-percentage components,
- the importance of DPP and traceability,
- the need for harmonised EPR incentives.

These themes appeared across brands, recyclers, technology providers and waste-management actors, which increases confidence that they reflect structural sectoral issues rather than isolated company-specific opinions.

Table12 - Frequency of cross-cutting themes in the stakeholder matrix

Theme	Stakeholders mentioning the theme	Approx. share of sample
Economic viability and cost gap	25/30	83%
DPP, traceability and labelling	25/30	83%
NIR, optical and automated sorting	27/30	90%
Elastane, additives, coatings and chemical legacy	17/30	57%
Design for Recycling / mono-materiality	19/30	63%
Harmonised EPR and regulatory alignment	30/30	100%
Mixed, multilayer and complex constructions	20/30	67%
Recycled-content demand and market pull	17/30	57%
Collection, infrastructure and regional hubs	20/30	67%

These frequencies should be read as indicative qualitative markers rather than survey statistics. They are based on coded occurrences in the interview matrix and support the interpretation of saturation, but they do not replace the detailed qualitative reading of each transcript. Their value lies in showing that the dominant issues are not confined to one stakeholder category.

The intermediate frequency of some themes should be interpreted in relation to the stakeholder categories that are directly exposed to those issues. For example, elastane, additives, coatings and chemical legacy were mentioned by 17 out of 30 stakeholders, corresponding to 57% of the total sample. However, this percentage does not mean that the issue is secondary. Rather, it reflects that the topic is highly specific to actors directly involved in recycling, fibre processing, sorting technology, product design and material recovery. Within these technically exposed categories, the issue was recurrent and can be considered representative of the stakeholders for whom such elements directly affect process feasibility, yield, purity and output quality.

In other words, the denominator should not always be the full sample of 30 stakeholders, but the subset of stakeholders for whom the topic is operationally relevant. From this perspective, elastane, additives and coatings appear as a highly representative concern among recyclers, technology providers and actors dealing with material compatibility, even if they were less frequently mentioned by stakeholders focused mainly on collection, reuse, policy or EPR governance.

A similar interpretation applies to recycled-content demand and market pull. Although mentioned by 17 out of 30 stakeholders, the theme was especially relevant for recyclers, spinners, fibre processors and material innovators, i.e. the actors whose business models depend directly on the existence of stable demand for secondary raw materials. For these categories, market pull is not a secondary issue but a core condition for industrial scale-up.

Mixed, multilayer and complex constructions were mentioned by 20 out of 30 stakeholders. This higher frequency reflects the broader impact of the issue across several value-chain stages, including design, sorting, dismantling, recycling and waste management. The topic is therefore both technically relevant and systemically visible, especially for carpet actors, chemical recyclers, sorting technology providers and waste-management operators.

Therefore, these frequencies should not be read as absolute rankings of importance, but as indicators of how widely each issue is perceived across the whole value chain. Some topics, such as elastane or chemical legacy, are highly specialised and may be mentioned by fewer stakeholders overall, while still being almost universal among the actors directly affected by them.

The observed frequencies should not be interpreted as a ranking of importance. Several themes are highly dependent on stakeholder exposure and position within the value chain. Consequently, lower frequencies may reflect a more specialised area of expertise rather than a lower strategic relevance. In several cases, themes such as elastane, additives, coatings, recycled-content demand and material complexity were mentioned by the majority—or even the entirety—of the stakeholder groups directly affected by these issues.

8. RESULTS DISCUSSIONS: GAPS, NEEDS, OPTIMAL SOLUTIONS AND REQUIREMENTS IDENTIFIED

The following sections present an integrated analysis of the questionnaire results. The analysis is structured around the four common interview questions used in Task T1.3 and then deepened through a comparison by stakeholder type. The goal is not only to summarise answers, but also to interpret how differences in business model, technical capability and position in the value chain influence the perception of strengths, weaknesses, opportunities and threats.

8.1 OVERALL INTERPRETATION OF THE STAKEHOLDER RESPONSES

A first cross-cutting result is that stakeholders do not perceive collection, classification, composition identification, sorting and labelling as separate problems. They describe them as an interdependent system. Collection without sorting creates low-value mixed waste; sorting without downstream outlets creates stockpiles and financial losses; composition identification without standardised data still leaves recyclers exposed to hidden contaminants; labelling without robust physical or digital persistence fails at end-of-life; and recycling capacity without market demand cannot scale.

The second general result is that the main challenge is no longer only technological. Many technologies already exist at pilot, demonstration or industrial scale: NIR sorting, hyperspectral imaging, colour sorting, AI-assisted image recognition, RFID/QR systems, chemical depolymerisation, selective dissolution, mechanical fibre opening, thermo-mechanical recycling and design-for-disassembly systems.

However, these technologies are not yet embedded in a coherent economic and regulatory system. In many cases, the limiting factor is not the absence of a technical solution, but the absence of viable feedstock flows, demand for recycled outputs and financial support for preparation steps.

The third result is that the textile sector cannot rely on a unique universal sorting logic. Different recycling technologies require different input specifications. Mechanical recycling is particularly sensitive to fibre length, fabric structure, colour and non-textile components. Chemical polyester recycling is more tolerant of some impurities but may require minimum polymer content and information on additives or coatings. Cellulosic chemical recycling requires cotton-rich fractions and is highly sensitive to elastane or certain polymeric contaminants. Carpet recycling requires knowledge of pile, backing, latex, filler and installation residues. A single generic category such as 'mixed textiles' is therefore insufficient for circularity.

8.2 QUESTION 1 - STRENGTHS IN COLLECTION, CLASSIFICATION, COMPOSITION IDENTIFICATION, SORTING AND LABELLING

The first question, which opens the interview, serves a dual purpose: to initiate a broader, cross-cutting discussion and to put the interviewee at ease and open to the discussion; the interviewee is asked to identify existing strengths and best practices. The answers show that the sector already possesses important building blocks for a circular textile system, although these strengths are unevenly distributed across product categories and geographical contexts.

Technology providers and research organisations highlighted the maturity of automated identification systems. NIR and hyperspectral technologies can already classify many textile streams by dominant fibre type and colour at industrial throughput. Several stakeholders reported that the accuracy of fibre detection has improved significantly compared with previous years, moving from broad ranges such as '90-100% cotton' to much narrower composition estimates. This indicates that automated sorting is no longer a purely experimental topic; it is becoming an operational pre-treatment tool for recycling.

Recyclers also recognised positive developments in pre-treatment. Some reported receiving cleaner feedstocks than in the past, with zippers, buttons and hard points increasingly removed before recycling. This is especially important for mechanical recyclers, for whom non-textile components can damage equipment and reduce fibre quality. For chemical recyclers, cleaner feedstock reduces operational risk and improves process control.

Another strength relates to controlled industrial and B2B streams. Post-industrial waste, production offcuts, workwear systems, contract carpet tiles, laundry textiles and recalled mattress components are often more traceable and more homogeneous than mixed post-consumer clothing. Stakeholders consistently indicated that these streams are easier to classify and recycle because origin, material composition and contamination levels are better known. This suggests that early circularity development may be more realistic in controlled streams before full-scale mixed post-consumer systems mature.

Carpet and flooring stakeholders provided a particularly clear example of the value of product design. Mono-material and duo-material carpets are easier to identify, sort and recycle than conventional hybrid carpets. Where manufacturers have redesigned products around material purity, end-of-life options become more credible. The same pattern appeared in apparel and technical textile discussions: simpler products, fewer material families and reduced accessory complexity all improve the feasibility of classification and sorting.

Collectors, reuse operators and waste-management actors highlighted the strength of existing collection networks. In several countries, textile collection routes already exist through municipalities, charities, social enterprises, bring banks, retailers, laundries and specialised operators. These networks provide the logistical basis for future EPR systems. However, their current strength lies more in collection for reuse or waste management than in high-purity sorting for recycling.

Labelling and traceability are still immature, but several promising practices were identified. These include QR codes on carpet tiles, RFID tags embedded in products, batch codes linked to internal ERP systems, printed or engraved recyclability markings, Digital Product Passport pilots, and product-level identification in closed-loop workwear systems. Stakeholders generally agreed that such systems can support classification if they remain readable at end-of-life and if they are harmonised across the sector.

Key implication for Circula-TEX

The stakeholder consultation demonstrates that significant progress has already been achieved in textile collection, sorting and composition identification technologies. Automated solutions such as NIR spectroscopy, AI-assisted recognition systems and digital traceability tools are increasingly available and capable of supporting industrial-scale operations. However, technological advances alone are insufficient. Future Circula-TEX activities should focus on facilitating interoperability between identification technologies, sorting infrastructures and downstream recycling processes to maximise the value of collected textile waste.

Table13 - Main strengths identified by stakeholder category

Stakeholder category	Strengths most frequently identified	Interpretation for T1.3
Technology providers / RTOs	NIR, hyperspectral imaging, AI-assisted classification, industrial throughput, multi-sensor pilots.	Automated sorting is technically feasible for high-volume categories, but needs harmonised targets.
Chemical recyclers	Ability to valorise fractions not suitable for reuse or mechanical recycling; process-specific impurity tolerance.	Sorting categories should be defined by recycler requirements rather than generic textile labels.
Mechanical recyclers / spinners	Experience with stable post-industrial streams, fibre-opening processes and application-specific quality requirements.	Fibre length, cleanliness and supply stability are essential classification parameters.
Brands / manufacturers	Capacity to influence design, material selection, product data and supplier specifications.	Upstream design can reduce downstream sorting burden.
Collectors / sorters / reuse operators	Existing collection networks, manual quality assessment and reuse market expertise.	Reuse-oriented sorting remains a valuable part of the waste hierarchy and should not be displaced by recycling.
Waste-management operators	Ability to manage non-recyclable fractions and provide fallback valorisation routes.	End-of-pipe actors reveal which streams still lack realistic recycling outlets.

8.3 QUESTION 2 - WHY CLASSIFICATION, COMPOSITION IDENTIFICATION, SORTING AND LABELLING REMAIN UNCLEAR AND UNSTANDARDISED

The second question addresses the issues that emerged from the preliminary analysis of the context (see Chapter 6 of this deliverable). The information gathered highlighted one of the main points of convergence. Stakeholders agreed that the textile sector remains unclear and unstandardised because of product heterogeneity, fragmented downstream requirements, unreliable information and weak economic incentives.

Overall, six main issues emerged.

The first reason emerged is material complexity. Textiles are not a single material stream. They include woven, knitted and nonwoven structures; apparel, carpets, workwear, home textiles, technical textiles and footwear; natural fibres, synthetic polymers and regenerated cellulosics; coatings, membranes, adhesives, prints, dyes, finishes, elastane, buttons, zippers and hard accessories. This complexity makes classification intrinsically more difficult than in sectors such as packaging, where material families are fewer and product structures are more standardised.

The second reason is the mismatch between current labels and recycling needs. Fibre composition labels are designed primarily for consumers and market transparency, not for recyclers. They often omit minor components, provide insufficient detail on additives and coatings, or are removed or damaged during use. Several stakeholders stressed that low-percentage components can be highly relevant for recycling even when they are legally negligible for labelling. Elastane, coatings, PFAS, adhesives or prints may be present in small amounts but can strongly affect depolymerisation, fibre quality, purity or process stability.

The third reason is the limitation of surface-based identification. NIR and optical technologies are considered a proficient technology but limited due often can read only the visible surface. They may therefore misclassify multilayer garments, carpet structures, coated textiles or denim with hidden elastane cores. This issue was repeatedly mentioned by chemical recyclers, technology providers and carpet actors. It indicates that future classification cannot rely only on dominant visible fibre identification.

The fourth reason is that recyclers are not asking for the same thing. Mechanical recyclers often require long fibres, low contamination and manageable fabric constructions. Chemical recyclers may accept more complex feedstocks but require knowledge of target polymer content and harmful additives. Carpet recyclers need to know backing systems, latex, fillers and installation residues. Reuse operators classify according to quality, style and market demand. Waste-management companies classify according to treatment suitability and calorific value. These divergent requirements explain why a single current standard has not emerged organically.

The fifth reason is economic pressure on sorting organisations. Sorting for reuse historically generated revenue through second-hand markets. Several stakeholders reported that this model is under pressure because incoming quality is declining and the proportion of non-reusable material is increasing. Sorting for recycling currently creates additional cost but limited revenue because many recycling markets are not yet mature. Under these conditions, operators have limited capacity to invest in standardisation, data systems and automated sorting without external support.

Finally, geographical fragmentation is a major factor. Waste streams differ between countries, seasons and market segments. Collection systems, municipal infrastructures, EPR schemes and sorting traditions also vary widely. Stakeholders therefore questioned whether a fully uniform European sorting standard is realistic. A more feasible approach may be to harmonise core data fields, quality classes and decision logic while allowing regional operational flexibility.

Key implication for Circula-TEX

The evidence suggests that the absence of harmonised classification systems is not primarily caused by technological limitations, but rather by the diversity of recycling pathways, stakeholder needs and end-use requirements. Future textile classification systems should therefore be designed around downstream valorisation routes rather than relying exclusively on fibre composition. A harmonised European framework should remain sufficiently flexible to accommodate the requirements of different recycling technologies and business models

8.4 QUESTION 3 - STRATEGIES FOR DEVELOPING STANDARDISED METHODOLOGIES

The third question invites the respondent to express their opinion on the development of sorting, composition identification and labelling systems.

Stakeholders proposed a broad set of strategies for developing standardised methodologies. The most important insight is that standardisation should not be understood as forcing all textiles into a single rigid classification. Rather, it should provide a common language linking product information, material condition, sorting outputs and recycling requirements. Overall, six main strategies emerged.

A first strategy emerged is to start from downstream requirements. Recyclers repeatedly argued that sorting categories must be meaningful for the technologies that will use the sorted material. This means that classification should include not only fibre family, but also target polymer content, contamination thresholds, fabric structure, quality condition, colour relevance, presence of elastane, coatings and accessories, and suitability for specific recycling routes. A recycler-led or recycling-outlet-led classification logic would reduce the risk of producing sorted fractions without buyers.

A second strategy is to combine technologies rather than searching for a single tool. NIR, hyperspectral imaging, RGB cameras, AI, RFID, QR codes, DPP, X-ray or inductive sensors, lateral sensors and manual quality assessment all have different strengths. Multi-sensor sorting platforms appear more realistic than reliance on one method. For example, NIR can identify dominant fibre composition, AI can support garment type and defect recognition, RFID/QR can provide product-level data where available, and manual sorting can still assess reuse quality and condition.

A third strategy is to develop harmonised Digital Product Passport data structures. Stakeholders generally supported the DPP as a key enabler, but with important conditions. The DPP must contain information useful for sorting and recycling, not only high-level sustainability claims. It should include detailed fibre composition, minimum thresholds, additives, coatings, dyes, finishes, recycled content, disassembly instructions, repair/reuse information and recommended end-of-life route. It must also remain connected to the physical product at end-of-life, which remains a major unresolved challenge.

A fourth strategy is to reduce product complexity through eco-design. Although the interview on design for recycling falls under Task 1.2, it often emerged that the interviewee made connections between topics spread across various tasks (it should be noted that the interviews were conducted simultaneously across different tasks, as described in Chapter 4), many stakeholders argued that the most efficient way to improve sorting is to simplify what enters the market. Mono-material or compatible-material products, fewer fibre families, fewer hard accessories, easier trim removal, limited chemical diversity and clearer design rules can reduce the burden on downstream systems. This does not imply eliminating all design freedom, but it requires setting boundaries around material combinations that create avoidable end-of-life complexity.

A fifth strategy is to create European knowledge-sharing platforms. Several stakeholders observed that municipalities, sorters, recyclers and manufacturers often work in isolation. Networks for exchanging best practices, standard specifications and operational data would support convergence. This is especially relevant for collection and sorting, where regional systems differ but face similar problems.

A sixth strategy is to use EPR as an economic stabiliser. This aspect relates to the questions concerning Task 1.5, as previously mentioned, since the interviews were conducted in conjunction with various tasks; it often emerged that the interviewee drew connections between the topics of different tasks. Interviewees consistently identified EPR as a potential source of funding for collection, sorting, preparation for recycling, technology scale-up, market development and eco-design incentives. However, they also warned that EPR must be harmonised and designed around real costs. If EPR fees support only collection but not preparation for recycling or downstream recycling capacity, standardisation will remain incomplete.

Key implication for Circula-TEX

Stakeholders consistently highlighted the importance of combining technological innovation with regulatory harmonisation. Future standardised methodologies should integrate physical material identification, digital information systems, recycling-oriented classification criteria and traceability tools such as Digital Product Passports. Circula-TEX can contribute by defining common data structures and classification principles capable of supporting multiple circular value chains across Europe.

8.5 QUESTION 4 - BARRIERS SLOWING EFFICIENT CLASSIFICATION, COMPOSITION IDENTIFICATION, SORTING AND LABELLING

The fourth and final question brought the interview to a close and asked stakeholders to identify barriers that may slow implementation. The answers confirm that the main barriers are interconnected and cannot be solved by technology alone. Overall, six main barriers emerged.

The dominant barrier is economic. Sorting for recycling has costs that are not yet covered by downstream revenues. Many recyclers cannot pay enough for prepared feedstocks because their recycled outputs compete with low-cost virgin materials. Brands often request sustainable materials but are reluctant to pay significant premiums. Customers and consumers remain price-sensitive. As a result, the business case for advanced sorting is weak unless supported by policy, recycled-content mandates or eco-modulation.

The second barrier is the lack of stable demand for recycled fibres and polymers. Stakeholders described a circularity paradox: sorters do not invest because recyclers are not fully scaled; recyclers do not scale because feedstock and demand are uncertain; brands do not commit because prices and quality are not yet competitive. This circular dependency slows the creation of standardised sorting streams.

The third barrier is contamination and hidden complexity. Elastane, coatings, PFAS, flame retardants, adhesives, prints, pigments, hard accessories, polyurethane foam and legacy chemicals were repeatedly mentioned. These elements can be technically difficult to identify and economically costly to remove. In some cases they create safety risks, such as self-heating in polyurethane-rich streams, or regulatory risks related to restricted substances.

The fourth barrier is the fragility of reuse and sorting systems. Several operators reported that the share of low-quality ultra-fast-fashion products is increasing while the resale value of collected textiles is decreasing. This undermines the financial foundation of sorting operations. If reuse revenues decline and recycling outlets are not yet strong, sorting organisations may struggle to survive precisely when more sorting capacity is needed.

The fifth barrier is regulatory fragmentation. Stakeholders repeatedly called for harmonisation because different national EPR systems, reporting rules, eco-modulation criteria and waste transport restrictions create administrative burden and market fragmentation. Without harmonised rules, companies operating across borders must adapt to multiple systems, reducing efficiency and weakening incentives for common methodologies.

The sixth barrier is insufficient product information. DPP and improved labels can help, but stakeholders warned that information must be reliable, detailed, standardised and accessible at the moment of sorting. If labels are removed, QR codes damaged, RFID tags too expensive, or DPP data too generic, the information system will not solve operational problems.

Key implication for Circula-TEX

The interviews indicate that economic and organisational barriers currently represent a greater challenge than technological readiness. Insufficient market demand for recycled materials, fragmented regulatory frameworks and limited alignment between collection, sorting and recycling infrastructures continue to slow implementation. Future Circula-TEX developments should therefore address not only technical solutions but also governance mechanisms, EPR implementation, eco-modulation criteria and market-enabling conditions.

Table14 - Main barriers and likely mitigation routes

Barrier	Stakeholders most affected	Possible mitigation
Weak economics of sorting for recycling	Sorters, collectors, recyclers	EPR support for sorting/preparation, recycled-content mandates, long-term offtake agreements.
Hidden materials and low-percentage contaminants	Chemical recyclers, mechanical recyclers, technology providers	DPP data, improved detection thresholds, pre-processing, eco-design restrictions.
Declining quality of post-consumer textiles	Reuse operators, sorters, waste managers	Quality-based classification, repair/reuse support, measures against ultra-fast-fashion low durability.
Fragmented EPR and national reporting	Brands, manufacturers, recyclers, PROs	EU-level harmonisation of core criteria, shared data model, common eco-modulation logic.
Multi-layer and complex products	Carpet actors, apparel recyclers, sorting technology providers	Design for disassembly, simplified structures, lateral/multi-sensor detection, dedicated recycling routes.
Lack of stable markets for recycled outputs	Recyclers, manufacturers, sorters	Mandatory recycled content, green public procurement, eco-modulation rewards, material certificates.

8.6 COMPARATIVE ANALYSIS BY STAKEHOLDER CATEGORY

The value of the stakeholder sample lies in the possibility of correlating answers with company type and practical experience. The following subsections summarize the main differences observed across stakeholder groups.

8.6.1 APPAREL BRANDS AND PRODUCT OWNERS

Apparel brands tended to focus on product design, internal development timelines, supplier engagement and regulatory compliance. Their answers were less operational on collection and sorting, but highly relevant for understanding upstream constraints. Brands generally recognized the importance of mono-materiality, reduced elastane and better composition data, but they also emphasized consumer expectations, aesthetics, price and long lead times as barriers.

Compared with recyclers, brands showed a stronger concern for the administrative complexity of EPR, DPP implementation and eco-modulation. They also highlighted the risk that simplified sustainability scoring systems may not capture trade-offs between durability, repairability, recyclability and environmental footprint. This perspective is important because brands are the actors that can influence product design before waste is generated, but they require clear and harmonised rules to justify design changes across global supply chains.

The brand perspective suggests that voluntary action alone will be insufficient. Where circular design increases cost or reduces design options, companies will need regulatory or market incentives. At the same time, brands can become key drivers of standardisation if DPP, EPR and eco-modulation criteria are aligned with product development systems.

8.6.2 Carpet and Flooring Manufacturers

Carpet and flooring actors provided some of the clearest evidence on the relationship between product architecture and recyclability. Conventional carpets are often multilayer products combining pile yarn, backing, latex, fillers, stabilising layers and sometimes installation residues. This complexity makes them difficult to identify and recycle. In contrast, mono-material or duo-material carpet systems are significantly easier to classify, sort and recycle.

These stakeholders also showed a strong distinction between post-industrial and post-consumer recycling. Post-industrial carpet waste is relatively controlled and can sometimes be recycled internally or externally. Post-consumer carpet waste is far more problematic because of contamination, legacy chemicals, installation adhesives and uncertain history. Carpet actors therefore stressed the importance of dedicated collection, product-level traceability and take-back systems, especially in B2B or contract markets.

A specific carpet insight is that the contract market can enable traceability and reuse more easily than the residential market. In commercial buildings, producers or facility managers may know where products are installed and can coordinate take-back. In residential carpets, products are sold through distributors or private labels, making end-of-life management much more fragmented.

8.6.3 Chemical Recyclers

Chemical recyclers provided the most detailed evidence on feedstock specifications, impurity tolerance and the limitations of current composition identification. They consistently argued that the suitability of a textile fraction depends on the target chemistry. Polyester, nylon-6 and cellulosic recycling technologies do not require the same inputs and do not have the same sensitivity to contaminants.

For polyester recyclers, key issues include minimum polyester content, dyes, coatings, elastane, polyamide, cotton and additives. Some technologies can tolerate relatively complex feedstocks, but they still need consistent information and pre-processing. For nylon-6 recyclers, elastane and additives are major obstacles, while selective dissolution and dedicated reverse supply chains are emerging solutions. For cellulosic recyclers, cotton-rich feedstocks are attractive, but hidden elastane and the regulatory treatment of pre-consumer or unsold textiles are important concerns.

Chemical recyclers were more likely than other stakeholders to argue that sorting must be downstream-driven. They do not need generic categories; they need material streams matching their technology windows. This suggests that future classification systems should include recycling-route compatibility rather than only fibre composition.

8.6.4 Mechanical recyclers, spinners and fibre processors

Mechanical recyclers and fibre processors focused on quality parameters that are sometimes overlooked in policy discussions. Fibre length, fabric construction, yarn twist, density, cleanliness, colour and supply stability are central to their operations. For these actors, a batch can be correctly labelled by fibre type but still be unsuitable if fibres are too short, fabric structure is too dense, or accessories have not been removed.

Mechanical actors often use flexible, customer-driven specifications rather than external fixed categories. This is because their outputs are adapted to downstream applications such as nonwovens, geotextiles, technical materials, yarns or industrial products. Exact precision, such as guaranteeing a specific count in recovered fibres, is often unrealistic. Instead, the priority is to maintain stable quality within a controllable range.

This group therefore supports classification systems that include material condition and quality classes. A purely composition-based taxonomy is insufficient for mechanical recycling. The most useful categories are those that describe not only what the material is made of, but what it can still do.

8.6.5 Collectors, sorters, reuse operators and waste-management companies

Operators involved in collection, sorting, reuse and waste management highlighted the operational reality of textile waste. They described increasing volumes, declining average quality, high manual labour needs, and economic pressure caused by reduced second-hand revenues. Their answers show that sorting is not only a technical activity but also a fragile business model.

Reuse operators emphasised human expertise in quality assessment. Manual sorters can rapidly evaluate wear, style, defects, resale potential and market demand. Automated technologies can support fibre identification, but they cannot yet replace human judgement for reuse. This is important because high-quality reuse remains above recycling in the waste hierarchy and should be protected.

Waste-management operators provided a complementary end-of-pipe view. They manage streams that currently lack recycling outlets, such as mixed workwear, complex carpets, shoes, polyurethane-rich products and contaminated textiles. These stakeholders show why circularity strategies must include fallback routes and must be realistic about fractions that are not yet recyclable at scale.

8.6.6 Technology providers, RTOs, research projects and clusters

Technology providers and research actors provided the strongest evidence on the maturity and limits of identification technologies. Automated NIR and hyperspectral systems are already industrially available, with high throughput and good performance for many dominant fibre categories. However, limitations remain for multilayer products, black textiles, low-percentage elastane, hidden components and chemical substances.

Research projects and RTOs also highlighted the importance of standardisation platforms, pilot lines, tagging methods and data architectures. Multi-sensor systems combining NIR, cameras, RFID, QR, AI and potentially lateral scanning are seen as more robust than single-sensor systems. However, stakeholders also warned that advanced technologies require investment and market certainty.

This category therefore indicates that the technological frontier is moving quickly, but it must be connected to real operating requirements. Without sufficient volumes, feedstock buyers and EPR support, even mature technologies may remain under-deployed.

8.7 ADDITIONAL INSIGHTS EMERGING FROM THE COMPARATIVE ANALYSIS

Beyond the four questionnaire questions, the interviews generated several additional insights that are useful for interpreting the sample and for developing recommendations. These insights are particularly relevant because they emerged from comparison between stakeholder categories rather than from single interviews.

8.7.1 1. SORTING SHOULD BE DEFINED BY DESTINATION, NOT ONLY BY COMPOSITION

The most recurrent strategic insight is that sorting must be linked to downstream outlets. A textile fraction has value only if there is a reuse, recycling or recovery route able to process it. This means that classification should include compatibility with specific recycling pathways. For example, a cotton-rich fraction may be suitable for cellulosic chemical recycling but not for mechanical spinning if fibre length is too short. A polyester-rich fraction may be suitable for chemical recycling but not for mechanical recycling if coatings or elastane exceed process tolerance. A carpet fraction may be recyclable only if pile and backing composition are known and installation contamination is limited.

8.7.2 2. DPP IS NECESSARY BUT NOT SUFFICIENT

Most stakeholders see the Digital Product Passport as a major opportunity, but they do not view it as a complete solution. DPP can provide information, but it cannot remove chemical complexity, create recycling capacity or guarantee that product identity survives end-of-life handling. DPP should therefore be treated as part of a broader system including physical marking, harmonised data fields, durable identifiers, sorting technology and eco-design requirements.

8.7.3 3. REUSE AND RECYCLING REQUIRE DIFFERENT SORTING LOGICS

Reuse-oriented sorting is based on condition, quality, style and resale market demand. Recycling-oriented sorting is based on material composition, purity, construction and process compatibility. These logics can conflict if the same infrastructure is expected to optimise both simultaneously. Future systems should recognise the hierarchy: first identify reusable items, then classify non-reusable fractions according to recycling suitability.

8.7.4 4. CHEMICAL INFORMATION IS BECOMING AS IMPORTANT AS FIBRE INFORMATION

Many recyclers stated that fibre composition alone is insufficient. Dyes, coatings, adhesives, PFAS, flame retardants, softeners, spin finishes and other substances can influence recyclability. The next generation of classification may therefore need a chemical-risk layer, especially for post-consumer textiles and technical products.

8.7.5 5. CARPET WASTE IS A DISTINCT SUB-SYSTEM

Carpets differ from apparel because they are heavier, often multilayered, may contain latex, fillers or backing systems, and are frequently linked to building or installation contexts. Carpet circularity may require dedicated collection hubs, building-level traceability, installation audits and carpet-specific DPP information rather than generic textile sorting rules.

8.7.6 6. Post-industrial and post-consumer streams should not be treated as equivalent

Post-industrial waste is generally cleaner, more traceable and easier to recycle. Post-consumer waste is more complex and less predictable. However, some stakeholders argued that pre-consumer scraps and unsold products should also be recognised as valuable feedstocks, especially for cellulosic recycling, because excluding them may slow the scale-up of technologies that can reduce virgin resource demand.

8.7.7 7. Economic mechanisms will determine whether technology is adopted

Across stakeholder categories, economic factors were more frequently mentioned than purely technical barriers. This suggests that guidelines should not focus only on best available technologies, but also on the financial conditions required for adoption: EPR fee allocation, eco-modulation, subsidies during scale-up, recycled-content demand, procurement and long-term contracts.

8.8 Gaps and needs identified in the co-creation activities

The stakeholder evidence allows the identification of gaps and needs across classification, composition identification, sorting and labelling. These gaps are summarised below as operational needs rather than abstract problems.

Table15 - Gaps and needs by T1.3 domain

Domain	Main gaps	Needs identified
Classification	Current categories are inconsistent and often based only on fibre type or resale quality. They do not systematically indicate recycling suitability.	A harmonised multi-layer classification including reuse potential, fibre family, product type, material condition, contaminants and recommended recycling route.
Composition identification	Surface-based tools miss hidden layers, low-percentage fibres and chemical treatments. Labels are incomplete or unreliable.	Multi-sensor identification, DPP-linked data, improved thresholds for elastane/additives and validated reference libraries.
Sorting	Sorting for reuse and sorting for recycling follow different logics; recycling streams lack stable outlets; sorting is financially fragile.	Downstream-driven sorting categories, EPR support for preparation for recycling, regional hubs and long-term recycler-sorter agreements.
Labelling	Current labels are consumer-oriented, may be removed and do not include additives, coatings or end-of-life instructions.	DPP plus durable physical identifiers, standardised data fields, batch/product traceability and end-of-life routing information.

8.9 SOLUTIONS EMERGING FROM CO-CREATION

The co-creation process identified several solution families. These should be understood as mutually reinforcing rather than alternative options

Overall, it emerged that, in the respondents' view, no single measure will resolve the issues of classification and selection; rather, effective progress will require a combined approach encompassing design, data, technology, infrastructure and policy.

The main aspects are:

- Development of harmonised recycling-route categories, defined with direct input from recyclers and sorters.
- Use of NIR and hyperspectral sorting as a baseline technology for dominant fibre identification, combined with AI and multi-sensor approaches for difficult streams.
- Implementation of DPP data fields tailored to end-of-life decision-making, including fibre composition, additives, coatings, trims, recycled content and recommended treatment route.
- Design-for-recycling guidelines prioritising mono-materiality or compatible material families, simplified construction, reduced elastane, limited chemical diversity and easier trim removal.
- Creation of regional sorting and pre-processing hubs capable of producing feedstock streams aligned with recycler specifications.
- Use of EPR fees to finance collection, sorting, preparation for recycling, technology scale-up and early-stage recycling markets.
- Development of quality-based categories for non-reusable textiles, including fibre length, cleanliness, wear condition and suitability for mechanical or chemical recycling.
- Protection of reuse through clear separation between reusable goods and recycling fractions, avoiding premature recycling of items with reuse potential.

8.10 REQUIREMENTS FOR CLASSIFICATION, COMPOSITION IDENTIFICATION, SORTING AND LABELLING DEVELOPMENT

Based on the interviews conducted, future systems should favour cases where certain requirements are met.

These requirements can support the development of a coding system for non-reusable textile streams and provide input for future EPR eco-modulation criteria.

Table16 - Proposed requirements derived from stakeholder evidence

Requirement	**Rationale**	**Possible implementation**
Route-specific classification	Different recyclers require different input specifications.	Include target route: reuse, repair, mechanical recycling, chemical recycling by polymer family, open-loop recycling, energy recovery fallback.
Minimum composition thresholds	Dominant fibre alone is insufficient for processing decisions.	Declare target polymer/fibre percentage and relevant secondary fibres above low thresholds.
Contaminant and chemical-risk flags	Small quantities of elastane, coatings or PFAS can block recycling.	DPP fields and sorting codes for elastane, PU/PVC, PFAS-risk, flame retardants,

Requirement	Rationale	Possible implementation
		adhesives, prints and coatings.
Product-structure information	Multilayers and backings are frequently misidentified by surface scanning.	Classify product type and structure. For instance: single-layer, multilayer, carpet tile, coated fabric, laminate … .
Quality condition class	Mechanical recycling and reuse depend on condition and fibre length.	A/B/C quality classes including cleanliness, wear, fibre integrity, odour and damage.
Persistent identification	Labels may be removed and QR/RFID can be damaged.	Use redundant systems: DPP, durable physical marker, batch code and fallback optical composition sorting.
Economic outlet verification	Sorting without buyers is not sustainable.	Define categories only where actual or planned recycling/reuse outlets exist, with periodic updates.

8.11 MAIN BARRIERS FOR EFFECTIVE EPR IMPLEMENTATION RELATED TO T1.3

Although this deliverable focuses on classification and sorting, the interviews show that EPR design will strongly influence whether technical solutions are adopted. Several barriers are directly relevant to T1.3.

First, EPR systems must avoid financing only collection. Stakeholders repeatedly indicated that the most fragile parts of the system are sorting for recycling, preparation for recycling and early-stage recycling capacity. If EPR support stops at collection, larger volumes of textile waste may enter the system without corresponding capacity to classify, prepare and valorise them.

Second, eco-modulation must be linked to real recyclability and not only to generic certification. Stakeholders warned that paperwork-based criteria may not change product design. Eco-modulation should consider material simplicity, recycling-route compatibility, presence of problematic substances, durability, repairability and verified recycled content.

Third, harmonisation is essential. Different national EPR systems may create divergent reporting categories and fee criteria, making it more difficult to develop common sorting methodologies. Stakeholders operating across countries strongly preferred harmonised European criteria or, at minimum, common core data fields and eco-modulation logic.

Fourth, EPR should create stable demand for recycled outputs. Without recycled-content requirements, procurement incentives or market support, recycling capacity may not scale. Sorting standards will be ineffective if sorted fractions cannot be sold.

Finally, EPR should recognise the diversity of textile products and recycling routes. A system designed only around apparel may not work for carpets, workwear, mattresses or technical textiles. Likewise, rules designed for polyester recycling may not fit cellulosic or nylon-6 recycling.

8.12 INTERPRETATION OF DIVERGENCES BETWEEN STAKEHOLDER GROUPS

Divergences in the interviews are not contradictions; they reflect different technical realities and economic positions. These differences are useful for developing nuanced recommendations.

Overall, the differences that emerged can be summarised in four main areas and, as discussed above, the issues of sorting, classification and labelling are intertwined with the issues analysed in the other tasks, in particular regarding design for recycling, the DPP and the EPR scheme.

A first divergence concerns the role of design. Product manufacturers and design-for-disassembly actors strongly emphasised Design for Recycling. Some chemical recyclers, however, argued that recycling technologies should be robust enough to process complex materials because performance requirements will continue to require additives and blends. This divergence suggests that policy should pursue both strategies: improve product design where feasible, while supporting recycling technologies able to manage legacy and unavoidable complexity.

A second divergence concerns DPP. Brands, carpet producers and many recyclers see DPP as essential for traceability. Some chemical recyclers and sorters were more cautious, arguing that information alone does not solve the problem if thousands of substances remain authorised or if the physical-digital link is lost during shredding. This suggests that DPP should be coupled with eco-design simplification and durable identifiers.

A third divergence concerns the preferred EPR governance model. Some stakeholders favour one PRO per country for simplicity and transparency; others support multiple PROs to stimulate competition; others prioritise harmonisation over the number of PROs. The common ground is that rules should be harmonised, administrative burden limited and fee allocation linked to real circularity outcomes.

A fourth divergence concerns the scope of recycling. Some stakeholders prioritise textile-to-textile recycling, while others argue that open-loop applications, insulation, construction materials, industrial products or SRF/RDF may be necessary for fractions that cannot yet be recycled into textiles. The analysis supports a hierarchy-based approach: preserve reuse and textile-to-textile where feasible, but recognise that alternative valorisation routes may be necessary for residual fractions.

8.13 IMPLICATIONS FOR CODING SYSTEMS AND FUTURE CLASSIFICATION ARCHITECTURE

The evidence supports the development of a coding system for sorted non-reusable textile streams. Such a system should be simple enough for operational use but detailed enough to support recycling decisions. The interviews suggest that a useful code should combine at least five dimensions:

1) product category;
2) fibre/polymer family;
3) structural complexity;
4) condition/quality;
5) contaminant risk.

For example, a cotton-rich single-layer white textile with low contamination and adequate fibre length should not be coded in the same way as a cotton-rich elastane denim with hidden corespun elastane. Similarly, a polyester garment with unknown coatings should not be treated as equivalent to a clean mono-polyester clipping stream. A carpet tile with traceable backing and batch code should not be grouped with mixed post-consumer carpet waste containing legacy latex and installation residues.

A practical classification architecture could therefore include:

a. reuse grade;
b. product family;
c. dominant fibre/polymer;
d. secondary fibres and threshold flags;
e. structure type;
f. colour class where relevant;
g. non-textile components;
h. chemical-risk indicators;
i. recommended end-of-life route;
j. confidence level of identification.

The confidence level is important because not all data sources have the same reliability: DPP data, labels, NIR scans and manual inspection should not be treated as equivalent without validation.

8.14 RECOMMENDED ANALYTICAL READING OF THE SAMPLE

The stakeholder sample can be understood as a systemic map of the barriers to circularity in the textile sector.

Several dynamics have emerged that suggest a holistic approach is needed to proactively address the issue of circularity within the European textile system. In particular, individual parties risk being unable to make significant decisions and take meaningful improvement actions precisely because of the lack of a harmonised systemic vision, which would also have the potential to resolve a series of bottlenecks that emerged during the interviews conducted. The main ones are:

- Upstream actors control design but depend on consumer acceptance and regulation.
- Sorters control the decision point between reuse and recycling but depend on revenue from reuse and buyers for recycling fractions.
- Recyclers define technical requirements but depend on prepared feedstock and market demand.
- Technology providers can improve identification but depend on investment and volumes.
- Waste managers handle residual streams and reveal the consequences of insufficient circular outlets.

The most important systemic insight is that each actor is waiting for another part of the system to mature:

- Brands wait for scalable recycled materials and clear rules;
- sorters wait for recyclers that can buy fractions;

- recyclers wait for stable feedstock and demand;
- technology providers wait for investment certainly;
- consumers lack information and incentives;
- policymakers seek standards but face fragmented technical requirements.

This coordination failure is precisely where harmonised EPR can play a strategic role.

The sample also shows that textile circularity should not be assessed only through technological readiness. Some technologies are available but underused because the economics are unfavourable. Other technologies are promising but need better feedstock. Some products are technically recyclable but logistically difficult to collect. Some labels provide data but not the data recyclers need. Therefore, the relevant unit of analysis should be the whole chain from design to end market, not individual technologies in isolation.

Strategic takeaway for Circula-TEX

The stakeholder consultation confirms that future textile circularity will depend on the ability to transform classification and sorting from operational waste-management activities into strategic functions supporting reuse, repair, remanufacturing and recycling. The most successful future systems will be those capable of combining harmonised classification methodologies, advanced identification technologies, Digital Product Passports, eco-design principles and EPR mechanisms within a coherent European framework. The findings generated through Task T1.3 provide a solid basis for the development of future coding systems, traceability architectures and policy recommendations within the Circula-TEX project.

8.15 CONTRIBUTION TO SUBSEQUENT CIRCULA-TEX ACTIVITIES

The evidence generated through T1.3 provides an essential foundation for the subsequent activities of Circula-TEX, particularly those related to the development of harmonised classification methodologies, coding systems, traceability frameworks, Digital Product Passport implementation and EPR-based circularity mechanisms. The findings are therefore expected to directly support Task 3.1 and the implementation-oriented activities of WP6, contributing to the development of interoperable and scalable solutions for textile circularity across Europe.

The analysis confirms that future textile waste management systems cannot rely solely on fibre composition as a classification criterion. Instead, classification approaches should be progressively aligned with downstream valorisation routes, recycling technologies, traceability requirements and EPR implementation mechanisms. This conclusion provides a foundational input for the development of future coding architectures and harmonised classification systems within the project.

Contribution to Task 3.1 – Development of Harmonised Classification and Traceability Frameworks

The stakeholder consultation conducted within Task T1.3 provides direct input to the activities foreseen in Task 3.1. One of the most consistent findings emerging from the interviews is that future textile classification systems should evolve beyond traditional fibre-based categorisation and incorporate additional information layers reflecting product complexity, recyclability and end-of-life requirements.

Stakeholders repeatedly highlighted the need for classification methodologies capable of integrating information related to:

- fibre composition and blends;

- presence of elastane and other problematic materials;
- multilayer and complex constructions;
- accessories and detachable components;
- coatings, additives and chemical treatments;
- recyclability potential and preferred recovery pathways;
- product traceability and data accessibility.

These findings provide a valuable evidence base for defining the structure, attributes and information requirements of future classification and traceability frameworks. In particular, the consultation supports the development of harmonised approaches capable of linking physical product characteristics with digital information systems and downstream valorisation routes.

The results also reinforce the importance of interoperability between different actors and data environments. Several stakeholders emphasised that future classification systems should facilitate communication between brands, collectors, sorters, recyclers, waste-management operators and regulatory bodies. Consequently, Task 3.1 can build upon the findings of T1.3 to develop frameworks that support both technical classification needs and information exchange across the textile value chain.

Furthermore, the consultation highlighted that classification requirements vary depending on the intended circular strategy, including reuse, repair, remanufacturing, mechanical recycling, chemical recycling and energy recovery. This observation suggests that future classification architectures should maintain a degree of flexibility while operating within a harmonised European framework, enabling different circular pathways without compromising interoperability.

Contribution to WP4 – Coding Systems and Classification Architectures

One of the clearest outcomes of the stakeholder consultation is the need to move from product-oriented sorting categories towards recycling-oriented classification systems. Stakeholders consistently highlighted that different recycling technologies require different feedstock specifications regarding fibre composition, contamination levels, additives, colour, construction complexity and accessory content.

The evidence collected through T1.3 will therefore contribute to the development of coding systems and classification architectures capable of:

- linking textile waste categories to downstream recovery pathways;
- supporting harmonised material identification across different actors;
- improving interoperability between collection, sorting and recycling systems;
- facilitating the generation of higher-quality secondary raw materials.

Particular attention should be given to the integration of information related to material complexity, fibre blends, elastane content, coatings, additives and non-textile components, which repeatedly emerged as critical factors influencing recyclability.

Contribution to Digital Product Passport and Traceability Activities

Stakeholders widely recognised the potential role of Digital Product Passports (DPPs) in supporting sorting and recycling operations. However, the consultation also demonstrated that DPP implementation will only be effective if supported by harmonised data structures and information fields that are relevant to end-of-life management.

The results of T1.3 provide a preliminary basis for identifying the information categories most relevant for future traceability systems, including:

- detailed fibre composition;
- information on coatings, additives and chemical treatments;
- recyclability and disassembly information;
- repair and reuse indicators;
- recommended end-of-life management routes.

These findings can support future project activities focused on interoperability, data exchange and product traceability.

Contribution to EPR Development and Eco-modulation Approaches

A recurrent theme across all stakeholder categories was the need for stronger economic incentives to support collection, sorting and recycling activities. Stakeholders consistently identified EPR schemes as a key mechanism for creating stable funding structures and promoting circular business models.

The results generated through T1.3 provide valuable evidence for future EPR-related activities by highlighting:

- the economic importance of feedstock quality;
- the role of sorting and preparation activities in enabling recycling;
- the need to reward products designed for circularity;
- the barriers created by complex multi-material constructions and insufficient product information.

These findings suggest that future eco-modulation mechanisms could incorporate criteria related to material simplicity, traceability, recyclability, disassembly potential and compatibility with established recycling routes.

Contribution to Harmonisation and Interoperability Objectives

A central conclusion emerging from the consultation is that harmonisation should not be interpreted as uniformity. Stakeholders recognised the need for a common European framework while simultaneously acknowledging that different textile products and recycling technologies require different operational approaches.

Consequently, future Circula-TEX activities should aim to develop harmonised yet flexible systems, based on common principles, shared data structures and interoperable classification methodologies rather than rigid uniform categories.

The findings of Task T1.3 therefore contribute directly to the broader objective of Circula-TEX: fostering interoperable solutions capable of connecting product design, collection, sorting, recycling and EPR implementation within a coherent circular textile ecosystem.

Strategic Message for the Project

Overall, the consultation demonstrates that technological solutions alone will not be sufficient to achieve large-scale textile circularity. Future success will depend on the simultaneous alignment of product design, traceability systems, sorting infrastructures, recycling technologies, market incentives and regulatory frameworks.

The evidence generated through T1.3 provides an essential foundation for this alignment and supports the development of practical, scalable and harmonised solutions that will be further explored in the subsequent work packages of Circula-TEX.

9. CONCLUSION

The analysis of the stakeholder questionnaires confirms that classification, composition identification, sorting and labelling are central enabling functions for textile circularity, but they cannot be improved in isolation. Their effectiveness depends on product design, data availability, sorting infrastructure, downstream recycling capacity, market demand and regulatory incentives.

The consultation shows a high level of convergence around several findings. Current strengths include improved NIR and automated sorting technologies, established collection networks in several countries, controlled B2B and post-industrial streams, emerging DPP/tagging solutions and growing awareness of Design for Recycling. However, classification remains unclear and unstandardised because textile products are highly heterogeneous, labels are insufficient, recyclers have different feedstock requirements, and sorting for recycling is not yet economically stable.

The main strategic recommendation is to move towards a downstream-driven classification system. Sorted fractions should be defined according to the requirements of reuse, mechanical recycling, chemical recycling and other valorisation routes. This requires harmonised terminology, shared data fields, quality classes, contaminant flags and clear compatibility criteria.

The analysis also confirms that DPP and improved labelling are essential but not sufficient. They must be accompanied by durable identification methods, better eco-design, reduced chemical complexity and robust sorting technologies. Similarly, automated sorting is necessary but will not solve the problem unless supported by viable end markets and EPR mechanisms that finance sorting and preparation for recycling.

The stakeholder sample is analytically robust because it covers the main functional positions of the textile value chain and demonstrates thematic saturation across core issues. While it is not a probabilistic statistical sample, it is sufficiently broad, diverse and consistent to support the development of project recommendations and future EPR guidelines. The differences between stakeholder categories are particularly valuable because they reveal where harmonisation is needed and where differentiated approaches are necessary.

Overall, the findings point towards a multi-layer solution: harmonised European EPR criteria, recycler-led classification specifications, DPP-enabled traceability, investment in automated and multi-sensor sorting, support for preparation for recycling, eco-modulation based on real recyclability, and policy measures creating stable demand for recycled materials.

These elements should be developed together to ensure that future textile waste systems can move beyond collection towards high-quality reuse, recycling and circular material recovery.

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